ENGINEERS AND GEOSCIENTISTS BRITISH COLUMBIA SEPTEMBER/OCTOBER 2017

INNOVATION

HEALTH AND SAFETY IN MINERAL EXPLORATION

CHALLENGES IN RISK ASSESSMENT

2017 PRESIDENT'S AWARDS

PM40065271

COURTING DISASTER

THE INCREASING CHALLENGE OF RISK ASSESSMENTS

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INTRODUCTION

On April 6, 2009, at approximately 3:32 AM, a magnitude 6.3 earthquake devastated the medieval Italian town of L'Aquila, about 90 km east of Rome, killing more than 300 and leaving thousands homeless. Ultimately, it wasn't just the devastating human toll that made this event newsworthy, but also the legal consequences to a group of Italian scientists that formed part of the Italian National Commission for Forecasting and Preventing Major Risks (the Major Risks Commission).

Those six scientists (three seismologists, a volcanologist and two seismic engineers) were tasked with estimating the risk of a major earthquake to the town in light of several small- and medium-sized events that occurred in previous months and those locals who had been predicting a major event. The Commission had estimated that there was little risk of a large earthquake. The earthquake occurred despite the commission's estimate, and in 2012, the scientists were sentenced to six years in prison and €9,000,000 in damages. The ruling was overturned two years later, but the impact to the global scientific community was sobering.

As geotechnical scientists and engineers, we are called upon to make judgments about the conditions and characteristics of the Earth and Earth processes. Those judgments are intended to guide development; to contribute to the understanding of environmental, economic, or societal safety; to advise civil design; and to prevent catastrophic outcomes of the human footprint. All too often we are expected to perform Herculean leaps

In 2009, a magnitude 6.3 earthquake devastated the medieval Italian town of L'Aquila, killing more than 300. Photo: "L'Aquila" UCL Mathematical and Physical Sciences - licensed under CC BY 2.0

of knowledge based on very limited data for a litigious society that relies on our expertise.

And let's be clear. The public does rely on our expertise, and as a self-regulating profession that claims expert knowledge about the workings of the Earth, we encourage and promote that model.

We owe ourselves, and the public, a duty of care to limit our own liability by being aware of, and communicating, what we know, and conversely what we don't know. We also owe it to ourselves and the public to clearly communicate the notion of residual risk and uncertainty, and how that residual risk can change as a result of changing conditions (including development).

DEFINITIONS

Definitions of hazard and risk may be superfluous; however, they are still widely misused in geotechnical engineering and warrant reviewing in light of the present topic.

Hazard

Hazard is widely used to describe threats to humans and what they value including life, well-being, material goods and the environment. Ambiguity arises wherein the term hazard is used as both a colloquialism and as a specialist term with different meanings or levels of precision for different disciplines. In geotechnics, hazard should be limited where practical to the probability, within a specific time and area, that an event or events (geotechnical, geological or geomorphological processes) will adversely affect humans or the things humans value. Other conditions can be described as threats, dangers, or susceptibility.

Risk

Risk is also widely-used to describe threats to humans and what they value. Geotechnical engineers and the public frequently misuse the word risk to mean hazard, or indeed, any measure of probability (such as susceptibility). Formally, risk must embody both the probability of a hazard (or the sum of hazards) occurring, and the consequence(s) of that event. The most general risk equation is given as:

$$R = H \times C$$

Where R=risk, H=hazard and C=consequence.

In reality, the basic risk equation is normally divided into component parts including: spatial and temporal probability of a hazard or a probabilistic model of hazards, the magnitude (volume, area, intensity, runout, etc.) of the elements at risk, and the value, vulnerability and exposure of those elements.

A more refined equation therefore looks something like the following:

$$R_S = P(H_{T,S} \times \sum(E_V \times V \times E_X)$$

Where R_S=specific risk, P=probability, $H_{T,S}$=temporal and spatial likelihood of a hazard of a given magnitude respectively, and E_V, V and E_X is the value, vulnerability and exposure respectively of a given element at risk.

It shouldn't surprise the reader to learn that many of these terms can be further broken down.

Residual Risk

Residual refers to the risk that remains following an event, assessment, or mitigation. It reflects our uncertainty about the stochastic nature of the physical world, the potential for even low probability events to occur at any time, and our knowledge and identification of more likely events that remain following an assessment or mitigation.

In the L'Aquila case, the knowledge of the day was that small earthquake swarms were not statistically correlated with a major earthquake (this assumption is being rigorously re-examined globally as a result of the outcome). The residual risk of a major earthquake remained but was inadequately communicated.

INCREASING RISK AND INCREASING CHALLENGES OF RISK ASSESSMENTS

While credible arguments can be made for a decreasingly risky world (increased lifespans, wealth and general

Aftermath of the 2009 L'Aquila earthquake
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human health, earthquake resistant infrastructure, better land use zoning, emergency management applications, and increased medical care), there are objective measures whereby geotechnical risk has increased substantially. With a global population at more than 7.5 billion and growing, humans have disrupted natural systems and imposed themselves on the landscape. Obvious examples include climate change and subsequent changes to sea level, slope stability, distribution of permafrost, flooding and storm intensity, as well as geotechnical risks that result from a systematic intrusion into, and occupation of, higher hazard areas.

The assessment of geotechnical risk cannot rely unquestioningly on standards and practices developed by those pioneers of the discipline. We must continue to use our best understanding and judgment in a world where the rate of change, and our role in it (as both drivers of change and those affected by change) is increasing, and our assessments should in some manner, account for that change. Errors in judgment are assured, but hopefully through the careful and judicious application of our knowledge, training and experience, and clear communication to our clients, we do indeed serve the public good.

Abdulahad *et al.* (2010)[1] reviewed 41 legal cases involving geotechnical practice in Canada between 1982 and 2006. While not strictly risk assessments, risk is implicit in each example. Of those cases, more than 50 percent were based on different soil conditions and recommendations than expected from the geotechnical report. The courts allowed the actions based on a provision of reasonable evidence to expect different soil conditions (about 40 percent of the time).

Nasmith (1986)[2] stated similarly that incorrectly located boreholes are among the most common errors in geotechnical engineering.

In addition, slope stability and landslide risk assessments are inherently high-risk for the practitioner. They rely on uncertain knowledge, changing ground conditions, and constantly changing driving forces (such as the weather, manipulation of the slopes, and re-direction of water among other things).

The questions remain: How do we, as a discipline, increase our predictive accuracy in an increasingly complex world? How do we communicate effectively to our clients both the legitimacy and the uncertainty in our work? How do we provide practical, useful advice that decreases geotechnical risk?

ANSWERS IN THE CODE

Geotechnical scientists and engineers conducting hazard and risk assessments perform a valuable public service. The engineers and geoscientists' code of ethics is designed to protect the public, but simultaneously offers protection to the practitioner. In this case, answers to the above questions are framed in the context of Engineers and Geoscientists BC's Code of Ethics:

Tenet 2: Undertake and accept responsibility for professional assignments only when qualified by training or experience.

It is a human condition to overestimate our knowledge or the accuracy of our own judgment. We're simply not very good at knowing what we don't know. An antidote to this is, ironically, training and experience. The more we learn, the more we are exposed to the exceptions to the rule, to the rare black swans, to solutions arrived at through an entirely different mechanism. We have a duty therefore, to recognize when independent or senior review is helpful (almost always) to cross-pollinate and discuss our ideas with peers and colleagues, to mentor junior and intermediate staff, and to approach other disciplines with respect.

Another antidote to the training and experience issue occurs when a problem is approached by an engineering geologist or geomorphologist and a geotechnical engineer working together. Each has a comprehensive background that is not likely to be fully realized by the other, but together can dramatically

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Chiesa delle Anime Sante. Damage to the dome of the Church of the Holy Spirit in L'Aquila following the 2009 earthquake. PHOTO: UCL MATHEMATICAL AND PHYSICAL SCIENCES - LICENSED UNDER CC BY 2.0

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improve the results of an assessment. These advantages were articulated early by Redlich, Terzaghi and Kemp, (1929), and many writers since, but the approach remains under-utilized.

Tenet 3: Provide an opinion on a professional subject only when it is founded upon adequate knowledge and honest conviction

Similar to the previous tenet and subject to the same solutions, this one also speaks to a tension that frequently arises between a client looking for a conclusive answer and a specialist who has insufficient data. Adequate knowledge is a judgment call and a practical balance between effort spent, and diminishing returns is often necessary. Nevertheless, there is a clear and logical relationship between increased data gathered through additional samples, boreholes, field work, LiDAR or similar means, and the accuracy of the result. Indeed, increased data was the first recommendation of Abdulahad *et al.* (2010) aimed at reducing legal claims against the geotechnical engineer, and it is the basis for the at least some of the changes in the new *Canadian Highway Bridge Design Code*, the upcoming seismic guidelines, and in general, reliability assessments in geotechnical engineering.

Where knowledge is insufficient, the uncertainty should be clearly communicated in such a manner that the client knows and understands what has been provided, but also what has not been provided in the assessment. Geotechnical baseline reports (GBR) are sometimes used to communicate the level of knowledge and reliability of geotechnical assessments. Baseline statements may be in conflict with the actual information gathered, but may be a more accurate description of what actual ground conditions could be. GBRs are not accepted by some clients, however, we can still provide clear communication about how our studies are to be used or interpreted.

Finally, where residual risk is known or assumed, that risk should be communicated as part of the information provided to a client.

Tenet 6: Keep themselves informed in order to maintain their competence, strive to advance the body of knowledge within which they practise and provide opportunities

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FEATURE

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for the professional development of their associates.

For the first time in history, as professionals, we are limited not so much by a lack of information as by an excess of it. Part of the corollary to the knowledge and training discussed under tenet 2 above, is the ongoing need to continue to advance our understanding, to learn what new applications, tools, knowledge, and software is available to us to adequately perform our jobs.

This is formalized through the association as professional development hours, and opportunities to expand one's knowledge and understanding will substantially improve one's ability to correctly assess hazard and risk.

In addition, where specialization continues to occur, it behooves us to learn what others can do, how it differs from our own skill sets, and to work in teams insofar as it is possible. This helps us reduce the famous "not knowing what we don't know" portion of the knowledge pie.

Tenet 8: Present clearly to employers and clients the possible consequences if professional decisions or judgments are overruled or disregarded.

The human mind is notoriously bad at understanding very large or very small numbers. Further, we are inherently drawn to a compelling narrative, sometimes drawing completely false conclusions about hazard and risk, and we are subject to inherent biases based on repeated experiences. For all these reasons and more, humans in general are very poor judges of actual risk, even when it is explained to us.

Unfortunately, hazard and risk assessments are routinely working with abstractions of probability, and individual human experience relates better to the repeated instances where nothing happened than the possibility that something unlikely will occur. We are like the proverbial Thanksgiving turkeys the week before the harvest, secure in our understanding about the benign and caring nature of the two-legged creatures that bring us daily food. There is a substantial challenge communicating credible risk scenarios to clients in a way that is not a scare tactic, but represents instead a genuine communication of probability, uncertainty, and residual risk.

Moving away from statements that discuss probabilities strictly in terms of return intervals (1:100 years, 1:10,000 years) and toward the percent probability of occurrence over a given period (design life, 50 years or similar) frames these numbers in a way that is more meaningful.

Similarly, we can articulate the ways that infrequent probabilities accumulate to better inform clients that manage large areas, long linear infrastructures, or intend to build facilities with a long design life.

Case studies or examples help illustrate the credible consequence scenarios for rare events that don't normally occur.

Ultimately, we have an obligation not to make a risk decision on behalf of the client, but to help the client understand what that risk really entails, and allow them to make an informed decision.

CONCLUSION

An argument can be made that the analysis of geotechnical risk is increasing worldwide. Consequences increase as the human footprint extends further into marginal lands, intersecting more hazards. Hazards increase, in part, due to new interactions between geomorphological and anthropomorphic systems that modify the surface of the planet and change the processes that form it. Our knowledge and understanding about geotechnical, geological, or geomorphological systems continues to increase, but requires increased specialization and training to use, and considerable effort to remain current.

The issues are not new, just increasingly complex. Possible solutions should be taken seriously as part of the service we provide, and to reduce our own liability that may arise through a failure of communication. The Engineers and Geoscientists BC Code of Ethics provides a framework for at least some of the answers within which geoscientists and geotechnical engineers can look for ways to provide reliable, transparent results, while helping clients understand how to best use and interpret them. The main points identified above are as follows:

- Get independent review of your work, solicit advice, mentor young staff;
- Respect specialization and work in teams, use engineering geologists/geomorphologists and geotechnical engineers together where possible (this may be a river hydrologist/civil engineer combination for rivers);
- Find adequate balance and communicate clearly the benefits of increased data and the risks associated with insufficient information. This is particularly true for locations where variability and the consequences are high (BC for instance);
- Provide language that helps clients understand how reports should be used and what other conditions might be expected;
- Communicate as applicable: confidence, uncertainty and residual risk;
- Increase your knowledge base and work with other specialists in complimentary fields;
- Recognize the inherent difficulty in understanding probabilities and find ways to communicate them in such a manner that a client is able to make knowledge-based decisions. ◆

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FOOTNOTES:

‹1› Abdulahad, S., Jergeas, G., & Ruwanpura, J. (2010). "A review of 41 legal cases involving geotechnical practice in Canada." *Canadian Geotechncial Journal*, 1047-1059.

‹2› Nasmith, H. (1986). *Suit is a Four Letter Word – A geotechnical engineers introduction to professional liability*. Victoria: BiTech Publishers Ltd.

‹3› Redlich, K., Terzaghi, K., & Kemp, R. (1929). *Ingenieurgeologie*. Vienna: Springer.